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METHOD AND DEVICE FOR RECOGNIZING VISUAL OBSTRUCTIONS IN IMAGE SENSOR SYSTEMS

Background Information

The present invention relates to a method and to a device for recognizing visual obstructions in image sensor systems.

In the future, in particular in conjunction with environmental sensing of motor vehicles, image sensors such as video cameras, for example, will be used whose image is evaluated by downstream functions (driver assistance functions, for example). It is therefore of particular importance to recognize visual obstructions which degrade the image detected by the image sensor, to inform the downstream functions or systems of the presence of such visual obstructions, and to initiate countermeasures if necessary.

Advantages of the Invention

The detection of the blurriness of the recorded image results in a suitable procedure which assists in recognizing visual obstructions. It is particularly advantageous that downstream systems or functions, which function properly only when the view is adequate, are informed of the presence of the visual obstruction and are thus able to initiate suitable countermeasures. When a visual obstruction is recognized, depending on the design of the downstream function or system the recorded image is advantageously not evaluated or corrected, or other suitable measures, such as switching on the windshield wiper system or windshield heating, for example, are performed.

It is particularly advantageous that visual obstructions are recognized based on the image signal itself, so that no additional sensors are necessary.

The procedure is suitable in particular for recognizing a visual obstruction on the windshield of the motor vehicle.

The image sensor advantageously takes over additional functions, such as the function of a rain sensor, for example, so that this rain sensor may be dispensed with in the furnishing of the vehicle with such image sensor-based driver assistance functions, for example lane monitoring systems.

The procedure described below is used in a particularly advantageous manner in video sensor systems in motor vehicles which are not focused on the vehicle windshield, but rather on the external region. The procedure described below may thus be used to particular advantage in conjunction with the sensing of the environment around a motor vehicle. In this manner the image sensor may be used for multiple applications (for example, rain sensor and object detection, etc.).

It is also advantageous that the image sensor is able to check its functionality using its own output signal, i.e., to determine whether the instantaneous view conditions are sufficient for the next function that is to be performed. When the image sensor is not functioning properly, this is advantageously signaled to the driver or the downstream system, and/or countermeasures are taken.

It has been shown in a particularly advantageous manner that the detection of visual obstructions is performed by measuring the blurriness of the represented image. A reliable method is thus provided for determining visual obstructions, in particular objects on a vehicle windshield, which appear blurry in the image. It is particularly advantageous that

transparent objects such as raindrops, or semitransparent objects such as ice or dust, for example, are recognized, and in one particular embodiment even distinguished from one another, by measuring the blurriness of the image.

Thus, it is also advantageously possible to obtain information about the type of visual obstructions. In this manner a response specific to the particular type of visual obstruction may be made, for example by automatically switching on the windshield washer system when the windshield is soiled by particles.

Further advantages arise from the following description of exemplary embodiments and the dependent claims.

Drawing

The present invention is explained in greater detail below with reference to the exemplary embodiments illustrated in the drawing.

Figure 1 shows an overview illustration of an image sensor system in which the procedure described below for determining visual obstructions is implemented; and

Figures 2 through 4 show diagrams with reference to which three different embodiments for determining the blurriness in the image and the recognition of visual obstructions derived therefrom are described.

Description of the Exemplary Embodiments

The image sensor system illustrated in Figure 1 is composed

essentially of an optical sensor array which is connected to a data processing unit 7, for example a microprocessor. The instantaneously visible scene is mapped onto the sensor array by a lens system 2. The image sensor is mounted behind a windshield 1 and is focused on the external region behind the windshield. The windshield is, for example, the window glass of a vehicle, in particular the windshield of the vehicle. The focusing on the vehicle's external region allows the image sensor system to also be used for other image processing operations such as lane detection or obstruction detection, for example. Evaluation unit 7 is composed of a module 4 for controlling lighting of the sensor array, a measuring unit 5 for estimating blurriness, and a decision module 6 which makes decisions regarding the presence and, optionally, the type, of a visual obstruction. In one preferred embodiment all of these modules are part of a microprocessor, the modules being implemented as software programs. In other embodiments, the modules are individual components (processors), likewise implemented as software, where estimations of blurriness are made, for example, in one component and decisions are made in another component. The decision made by decision module 6 is then relayed as an information and/or activation signal to downstream functions and/or systems. Application possibilities are described in greater detail below.

The automatic detection of visual obstructions on the windshields of a vehicle therefore plays an increasingly important role due to the fact that, when image sensors are used in the vehicle, systems which evaluate the images from the sensor function properly only when the view is adequate. If there is information about the visual obstruction and, in the ideal case, about the type of visual obstruction, such a system is able to display to the driver its instantaneous lack of functionality and/or to take countermeasures, such as switching on the wiper system, windshield heating, windshield washer system, for example.

When visual obstructions are determined based solely on the image sensor signal, the problem arises that visual obstructions on a vehicle windshield are made noticeable in the image only indirectly, since for use in driver assistance systems the image sensor is focused on the vehicle's external region. Objects on the windshield, for example raindrops or dust, are therefore blurrily imaged. These visual obstructions are thus made noticeable by a characteristic distribution of the blurriness in the image signal.

The detection of visual obstructions is based on measuring the blurriness of the image which is recorded by an image sensor. This blurriness is made noticeable by a lack of sharpness of the imaged contours of the instantaneously visible scene. Objects present on the windshield are blurrily imaged due to the focusing of the image sensor on the external region. Transparent objects, such as raindrops, for example, result in localized defocusing of the image, and semitransparent objects such as ice or dust scatter incident light beams. Both effects result in an increase in the blurriness of the sensor signal. The evaluation unit which is associated with the image sensor, an optical sensor array of, for example, a CCD or CMOS camera, detects the distribution of blurriness of the instantaneously imaged scene. Based on the detected distribution of blurriness, a conclusion is drawn as to the presence of a visual obstruction. One of the methods for digital image processing described below is used for determining the blurriness.

In one preferred embodiment, the image sensor is a sensor array which assists in obtaining information also on the type of visual obstruction. This fundamentally distinguishes such a sensor array from a conventional rain sensor which operates by the reflection principle. The use of a sensor array allows a specific response to be initiated to the determined visual obstruction, for example, by additionally switching on a

windshield washer system for soiling caused by particles. One preferred procedure for recognizing the type of visual obstruction is likewise described in detail below.

A first possibility for measuring blurriness is illustrated with reference to the diagrams in Figure 2. Blurriness is measured here using the contrast spectrum. The underlying principle of this method is known from the field of digital image processing. To obtain the contact spectrum, first a multiscale analysis is carried out in which the video image is decomposed into multiple images of decreasing resolution by the repeated use of a smoothing operation and subsequent subsampling. A global measure of contrast, for example the standard deviation of the intensity values in the image, is calculated in each resolution stage. The measure of contrast plotted as a function of the resolution forms the contrast spectrum of the image. Examples of such contrast spectra are shown in Figures 2a and 2b. In these figures, the particular measure of contrast K of the image is plotted as a function of resolution A. Sharp and blurry images differ in their contrast spectra by the fact that the drop in contrast as a function of increasing resolution is steeper in blurry images than in sharp images. This is because fine details are degraded more strongly by visual obstructions than are coarse image features. Thus, the drop in the contrast spectrum is a measure of the blurriness of the image. Situations are shown as examples in Figures 2a and 2b. Figure 2a illustrates a contrast spectrum as a function of the image resolution for an image with slight blurriness, while Figure 2b shows the situation for high image blurriness (blurry image).

In one implementation of the procedure for determining the blurriness of the image, the contrast spectrum is recorded by multiscale analysis within a computing program, and a variable is determined, for example the average increase in the measure of contrast as a function of the resolution, which

characterizes the variation of the measure of contrast as a function of the resolution. The blurriness of the image is determined by comparing this variable to at least one limiting value. For recognizing a visual obstruction, in particular with regard to the response measures planned in the downstream systems, it is sufficient to determine that the image is blurry; thus, the determined variable is compared to a limiting value, and if this limiting value is exceeded, blurriness may be assumed, or the variable itself is relayed as a measure of blurriness. In other applications, determining a measure of the blurriness is desired. In these cases, limiting values form ranges for the variable which characterizes the contrast spectrum and to which blurriness values are assigned. A value for the magnitude of the blurriness is determined when the value characterizing the contrast spectrum is in a specified range of values.

In addition to measuring the blurriness by using the contrast spectrum, there are a number of other methods from the field of digital image processing that may be used to detect blurriness. Examples of such alternative methods for measuring the image blurriness are measures for analyzing the Fourier spectrum or the autocorrelation of the analyzed image. In the Fourier spectrum a blurry image is characterized by the fact that the amplitudes of the high spatial frequencies, which represent the finer image details, are strongly attenuated in comparison to a sharp image.

Examples of such a situation are shown in Figures 3a and 3b. The curve of the Fourier spectrum is plotted in both figures, the amplitude of the Fourier transformation function being represented by the spatial frequency. Figure 3a shows a slightly blurry image, while Figure 3b shows a highly blurry image. It is obvious that the amplitudes at the higher spatial frequency decrease greatly for a blurry image. For evaluation, in one preferred embodiment it is therefore provided that the

amplitude and the corresponding spatial frequency are used to recognize values that fall below a threshold value. If this spatial frequency is below a predetermined value, it is assumed that the image is blurry. In another embodiment, the slope of the curve could also be used here to determine blurriness by comparing it to at least one limiting value. For the evaluation of the Fourier spectrum as well, it is possible to determine a value for the magnitude of blurriness by specifying multiple limiting values or by specifying value ranges, and relaying this value to downstream systems.

A third possibility for measuring blurriness is the autocorrelation function of the image. This autocorrelation function decreases less steeply for a blurry image than for a sharp image as a function of distance. This is because only large structures remain in a blurry image. Figure 4 illustrates this relationship, the particular magnitude of the autocorrelation function being plotted as a function of the pixel separation. Figure 4a shows the autocorrelation function for a slightly blurry image, and Figure 4b shows the autocorrelation function for a highly blurry image. The figures show that as the pixel spacing for an image having a low degree of blurriness (sharp image) increases, the autocorrelation function rapidly decreases, whereas for a blurry image the decrease in the autocorrelation function is less. As indicated above, for the evaluation it is possible to use at least one limiting value or multiple limiting values being exceeded or not being attained, or, in another embodiment, to use the calculated average increase to determine the blurriness and/or to determine a value for the magnitude of the blurriness.

A further alternative for measuring blurriness is provided by an indirect classification formulation in which a learning machine, a neural network or a polynomial classifier, for example, is trained to distinguish between blurry and sharp

images by presenting a large number of images as examples.

As mentioned above, a visual obstruction is assumed when a high degree of blurriness is recognized, or the value of the blurriness is greater than a predetermined value. In addition, a comparison to reference distributions for contrasts, Fourier components, or autocorrelations may differentiate various types of visual obstructions based on their similarity to specific reference distributions. In this manner it is possible to distinguish moisture on the windshield from ice or dust on the windshield, and, depending on the situation, to initiate different countermeasures, for example, activation of the windshield wiper, switching on a windshield heating system or a windshield washer system, etc. Here as well, the above-referenced classification formulation may be provided by learning machines.

If the video sensor having visual obstruction detection is also operated as a rain sensor, further additions are useful. If moisture on the windshield is recognized based on the determined blurriness and the contrast distribution, or the Fourier spectrum or autocorrelation, the windshield wiper is, as previously, initially actuated only at the explicit request of the driver, to prevent erroneous start-up when an error is detected. Using the video images which are recorded immediately after the wiping operation, it is possible to obtain the above-mentioned reference distributions, using which a decision is made to initiate the next wiping operation. Thus, the wiping response may be adapted on a situation-specific basis. For situations in which the surrounding scene contains too little contrast, it may be practical to temporarily switch on a windshield light. Visual obstructions are then detectable from the scattering of the light.